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Design of Sustainable Construction Through Value Engineering of an Automated People Mover System Project

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Abstract. Sustainability infrastructure has become a crucial issue among decision-makers, developers, contractors, and consultants around the world. Value Engineering (VE) program is a method for improving project sustainability. This method present whether a decision increased or worsens the project's performance. The purpose of this study to create and evaluate alternative ideas for expanding the project value. This study proposes VE analysis at the design level to achieve optimal project costs and duration. The case study is carried out on the Automated People Mover System (APMS) project. APMS project, at Soekarno Hatta International Airport, is the first Sky train in Indonesia. The length of the APMS track is 3.05 kilometres. APMS tracks are using for a simple pan bridge structure. On the APMS project, the initial design of the girder used the PC-U type with rarely-used dimensions. By using the VE program, stakeholders decided to replace PC-U type with the PC-V type, which has standard dimensions in PT. WIKA BETON as a supplier. The use of a PC-V type girder gains the benefit of efficiency in terms of time and cost. The percentage of production and erection time of the PC-V girder is 97% faster. Besides, the percentage of cost-saving is 9% of the total project cost.

1. Introduction

As sustainability is an essential requirement for all industrial processes, including the construction industry. The construction project is an activity that is completed in a limited time using specific resources to obtain the best results. Resources are a determining factor in the success of a construction project. The influential resources in construction projects consist of man, materials, machines, money, and methods. VE and sustainability could be the best way of lean construction principles and saving life cycle cost [1]. Value Engineering (VE) is a management technique that uses a creative, innovative, and systematic approach to find a balance between cost, reliability, and performance (value) of a product or service [2]. In other words, VE aims to create something optimal for the amount of money that will be spent [3]. This VE study was conducted at the Automated People Mover System (APMS).

APMS project. APMS is a new mode of transportation at Soekarno-Hatta Airport. APMS will be integrated directly with the Commuter Line Station from Manggarai Station to Soekarno-Hatta Airport. Also, APMS will connect terminals 1,2, and 3 of Soekarno-Hatta Airport. The construction of



this project uses the Girder structure as the main beam that can accommodate a load of ± 300 tons. The girder structure has a length of ± 30 m between the pier columns.

However, in the initial design to Detail Engineering Design, girder material was changed from PC-U girder to PC-V Girder. Because of this, to find out the efficiency of changing the type of girders, a VE study is needed. In this study, the application of VE aims to enable the contractor to project cost savings using other alternatives without reducing quality so that effectiveness and time efficiency are achieved [4]. VE analysis is applied to the conceptual or design stage [5]. So that no stakeholder is harmed, but VE benefits both stakeholders between the contractor and the owner.

2. Literature review

Value Engineering is a multidisciplinary-based structured decision-making process [6]. VE analysis to achieve the best value of a project by defining the functions needed to make the best value at the optimum cost, with the required quality and performance [5].

VE is a method for cost savings by using a systematic approach to get the best balance between functions, and the performance of a project [2]. The purpose of VE is to separate what is needed and not. Alternatives are developed to get rid of unnecessary with the lowest cost but the same or even better performance [7]. The savings obtained from the application of VE include cost savings and time savings.

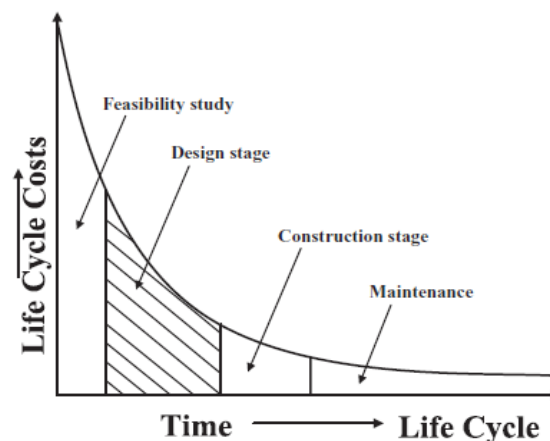


Figure 1. Impact of the VE practice on costs

From the picture above, it can be described that each project's life cycle results in different cost savings [2]. VE method can be used in every phase of the project. The VE technique is more effective when used in the conceptual and design aspects. VE techniques can increase opportunities for better cost reduction [3]. In this case, the VE technique evaluates various alternative ideas in the design stage to establish cost savings.

3. Research methodology

Value engineering methodology is a systematically arranged phase known as a value engineering job plan [1]. The value of the project is obtained from the comparison between performance and cost [8]. So the VE technique must be applied in teamwork. According to [7], the phase of implementing the VE technique to get an efficient design consist of 4 (four) phases:

3.1 Information phase

The information phase aims to collect various project data. In this phase, the VE team must understand the project objectives, technical specifications, and original design consultants [9]. In this research, the work of the girder structure is using a Value Engineering study.

3.2 Creative phase

The purpose of the creative phase is to determine alternatives that will be used in VE analysis of the girder structure. These alternatives can be assessed from various aspects such as material, construction dimensions, time work, and construction method. Creative ideas using a brainstorming technique are created in the VE team discussion [10]. VE members are not permitted to underestimate other alternative approaches [9].

3.3 Analysis phase

The analysis phase is the stage where the VE team evaluates and selects alternatives to find the best alternative design to replace the original design for the selected work item and calculate cost and time savings. VE team identifies the benefits of each alternative [10].

3.4 Evaluation and recommendation phase

The evaluation and recommendation phase is the phase of collecting all the results starting from the information phase, the creative phase and the analysis phase, which will be summarized so that the value of the initial costs and the costs of the selected alternatives can be known. So that it will be remembered the work items that can be replaced and how much cost savings obtained after VE implementation. All team project must accept with VE analysis results [7].

4. Result and discussion

4.1 Information phase

Primary data consisting of project description, budget plans, and structural design is obtained from PT. Wijaya Karya as a contractor. Secondary data were collected through structured interviews with five contractor engineers.

Table 1. Project cost recapitulation

No	Scope of Work	Cost Percentage (%)	Cumulative Percentage (%)
1	Preparatory Work	8,3	8,3
2	Structural Work	49,3	57,6
3	Shelter Work	40,1	97,7
4	Finishing Work	1,0	98,7
5	DED Work	1,1	99,8
6	Other	0,2	100

Table 1 above shows the APMS project cost recapitulation. From this table, it can be seen that structural works require the highest costs, with a percentage of 49,3 %. Then, a Pareto chart is made to illustrate the relationship between the scope of work and the percentage of cumulative costs

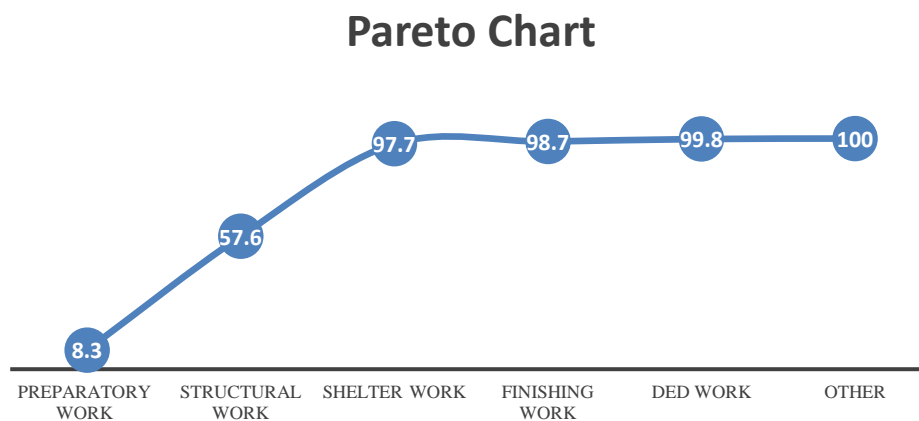


Figure 2. Pareto chart of overall project costs

Figure 2 above shows the structural work can be further analyzed because, in the Pareto chart, the percentage is 49,3 % of the total project cost.

4.2 Creative phase

From the Pareto analysis, VE is focusing on the girder structure. In the initial design of the girder used the PC-U type with rarely-used dimensions. Then, the alternative that will be developing is to replace the type of PC-U girders with PC-V girders. This alternative is because the use of PC-V girders can provide cost savings for companies and accelerate the overall duration of the project.

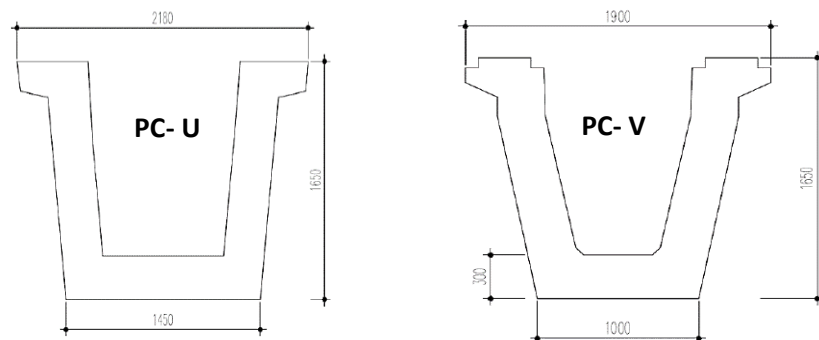


Figure 3. Girder type

4.3 Analysis phase

In the analysis phase, PC-U girder and PC-V girder will be compared with 3 parameters, including concrete volume, cost, and duration.

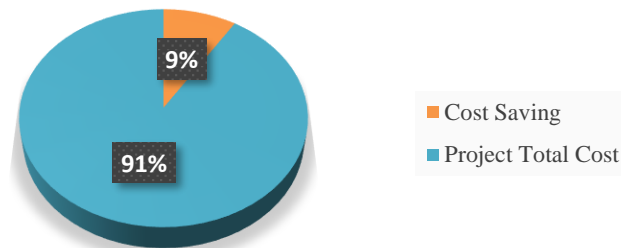
Table 2. Concrete volume comparison between PC-U girder and PC-V girder

	PC-U Girder	PC-V Girder
Area (m ²)	2,349	2,11
Length (m)	30	30
Volume (m ³)	70,47	63,3

Table 2 presents that using a PC-V girder requires a volume of concrete that is more efficient than PC-U girders. The concrete volume will affect the purchase price of the girders. The table below informs the cost comparison between PC-U girder and PC-V girder.

Table 3. Cost comparison using PC-U girder and PC-V girder

	PC-U Girder (Rp)	PC-V Girder (Rp)
Total Cost/Span	685,492,908.00	625,911,552.00,-

**Figure 4.** Percentage of cost savings using PC-V girder

Most influence factor of the cause of the material cost is the production process [10]. PC-U girder requires a higher cost because the supplier must make a new mold because the dimensions of the initial design are not available in the supplier. From figure 2 above, drawn PC-V girder provides an efficiency of 9% of the total project cost.

Table 4. Comparison of production time using PC-U girder and PC-V girder

No	Description	Type	Week 1	Week 2	Week 3	Week 4	Week 5
1	Mold Design	PC-U Girder	 TOTAL DURATION 31				
		PC-V Girder					
2	Mold Procurement	PC-U Girder					
		PC-V Girder					
3	Mold Production	PC-U Girder					
		PC-V Girder					
4	PO Mold	PC-U Girder					
		PC-V Girder					
5	Girder Production	PC-U Girder					
		PC-V Girder					
Total production time		PC-U Girder	31 days				
		PC-V Girder	1 day				
Information			Molds are available Girder Mold Production Girder Production				

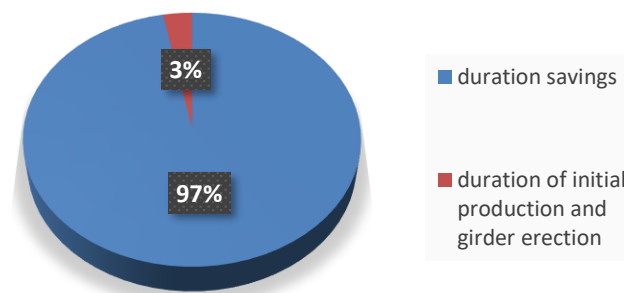


Figure 5. Percentage of time savings production and erection girder

PC-U girders require a longer production time because the dimensions of the girders are not available at the supplier, so the supplier should make a new girder mold. From figure 3 shows the duration saving by using a PC-V girder with a percentage of 97%. Besides, from the results of the girder strength analysis, the stability of the PC-V girder is also safe against torque.

4.4 Evaluation and recommendation phase

At this stage, it is recommended that the structure of the girder, which was early used as a PC-U girder, be replaced by a PC-V type girder as an alternative. Because of cost-saving, duration saving, and also the structural strength that fulfills the strength requirement.

5. Conclusion and Suggestion

VE analysis is used to determine alternative types of girders as a substitute for the early design of girders that is more efficient in terms of cost and time of the APMS project. VE analysis of PC-V girder resulted in cost-saving as much as 9 % of the total project cost. PC-V Girder resulted in duration saving as much as 97% of the total duration of production and erection girder. VE is a multidisciplinary and complex method that requires VE experts to get more alternatives. Besides, VE can not only be carried out on high-cost structural works but can also be performed on other tasks such as on architectural, mechanical, and electrical to calculate labour efficiency or project duration.

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